Fish Habitat Assessments of the Lardeau River (2002) Integrated with Habitat Assessments of the Duncan River.

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For

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By Pat Slaney and Harvey Andrusak

Introduction

Kootenay Lake provides a major inland sport fishery which attracts large numbers of tourists from Alberta and neighboring US states, as well as resident anglers from British Columbia. The Gerrard strain of rainbow trout is the main focus of the Kootenay Lake fishery, which has ranged from 25,000 to 50,000 angler days per year (Redfish Consulting Ltd 2003). These renowned trophy-sized rainbow are produced in the Lardeau and Duncan rivers (Irvine 1978). The former flows from its origin at Trout Lake for about 40 km to its confluence with the Duncan River, which flows a further 10 km into the North Arm of Kootenay Lake. There has been considerable research on Kootenay Lake (Northcote 1973, Ashley et al. 1997), largely because of shifts in its trophic status, but there is only a limited amount of information available on the lake's most important free-flow tributary, the Lardeau River. Yet, the Lardeau River provides vital spawning and rearing areas for the recruitment of Gerrard rainbow trout. Conservation of this exceptionally important wild trout population is dependent not only on cautious management of the fishery, but also on sound protection and management of habitat of the Lardeau and Duncan rivers.

The Lardeau-Duncan system lies within the Purcell Trench, and flows in a northern to southern direction. The Lardeau watershed is located within the Interior Western Hemlock biogeoclimatic zone. Precipitation, water temperatures, and flows are described elsewhere (Irvine 1978, Redfish Consulting Ltd. 2003). In the Lardeau and Duncan rivers, total dissolved solids are 79 and 69 mg/l, respectively, or a moderate level. There is limited data available on nutrients, but because both rivers are lake-headed, the N:P ratios indicate summer P deficiency (Perrin and Korman 1997).

Land-use practices of the past are recognized to have long-term effects on the fluvial geomorphology and the salmonid habitat of streams (Slaney and Martin 1997). Past logging to stream banks of most streams in the Pacific Northwest has resulted in profound changes. Substantial channel widening and bank erosion can occur in some channel types over time, as documented by Millar (2000) at Slesse Creek in the Chilliwack watershed. Similarly, reductions in the frequency of large wood can substantially reduce pools, which are documented to reduce salmonid carrying capacity (Murphy 1995, Slaney and Martin 1997).

The Lardeau and Duncan Rivers have had extensive logging development since the early 1900s when a railroad was constructed along the length of the Lardeau River. The railway was subsequently converted to a mainline road that is currently part of the provincial highway system. Much of the floodplain and the riparian zone of these rivers were logged to their banks within the past 100 years

(Alexander 1998). In addition, the Duncan River was impounded for downstream hydroelectric purposes in the 1960s, and this has greatly altered the seasonal nature of the river's hydrograph (Figure 6 in Vonk 2001).

To the uniformed observer, habitat changes resulting from past land use can be imperceptible because they occur so gradually. Most wood decays at 3 % a year in streams, and large woody debris (LWD) is lost at a rate of 5 to10 % a decade (Koski 1992). Furthermore, large log jams that are more persistent than other habitat features may obscure subtle and more insidious impacts, yet to a causal observer, the system from a distance may appear complex or even pristine.

The purpose of this report is to summarize results of the fish habitat assessment procedure (FHAP), which was applied to the Lardeau River to examine habitat conditions, using the method described by Johnston and Slaney (1996). A secondary objective was to review fish habitat studies conducted on the Duncan River by R. L. & L Environmental Services and summarized by DVH Consulting Ltd. (Vonk 2001), to integrate habitat surveys with that of the Lardeau River. Given the large size of these rivers, this is a preliminary assessment of existing habitat conditions. Fish habitat summaries and modeled estimates of parr production capability for 2002 for Gerrard rainbow are provided in Redfish Consulting (2003).

Methods

The Fish habitat assessment procedure (FHAP) originated in the Pacific Northwest for quantitatively assessing the effects of past logging activities on forested streams (Schuett-Hames et al. 1994). The procedure was adapted for use in British Columbia (Johnston and Slaney 1996), and ideally it should be applied using diagnostic data collected from old-growth forested watersheds similar to the targeted watershed. Where diagnostic data is unavailable, generic diagnostics are utilized (Table 5 in Johnston and Slaney 1996). During the Watershed Restoration Program of 1994-2002, an unpublished evaluation of the technique by the Ministry of Water Land and Air Protection provided support for its use, particularly for the large wood diagnostics.

The procedure may have some limitations, in that it was developed mainly for small to medium sized streams with channel width in the order of 15 m. Thus, there are uncertainties on how well it applies to larger rivers with channel widths of 70 m, as found in the Lardeau River. Yet, it should apply reasonably well to the Lardeau because the channel and habitat features are very highly influenced by large wood, but its application to the high-flowing Duncan River could be more challenging. Regardless, considering the importance of the Lardeau River, there is a need to examine habitat conditions, and to use such a procedure to proactively gain insight into the trend of future conditions. The procedure is also designed to identify opportunities for restoration or for offsetting impaired conditions and lost habitat, which is summarized in more detail in Redfish Consulting (2003).

The Lardeau River was sub-sampled over 20% of its length by randomly selecting 1-2 km sub-sections within six reaches (Figure 1). Lengths of the six reaches ranged from 6.4 km (Reach 1) to 7.1 km (Reach 2-5) to 8.8 km (Reach 6). Hydraulic units were separated into riffles, glides and pools and several physical characteristics were measured with a meter rod and a laser range finder, the latter accurate to + or - 1.0 m. Measurements included lengths of hydraulic units (riffle, glide pool), bankfull width, wetted width, bankfull depth, mean wetted depth, maximum pool depth, and residual pool depth.

Two well-experienced observers also made consensus estimates on several other features, thus minimizing error. Parameters included dominant substrate size, sub-dominant substrate size, gradient, surface velocity, percent total cover, percent boulder cover, percent large woody debris in pools, and cover types per habitat unit.

Total large wood, defined as all wood >2 m in length and >10 cm in diameter, was counted within the bankfull channel. Functional large wood was that which influenced the nature of the hydraulic units in terms of scour and cover, and it was counted by size category according to basal diameters of 10-20, 20-30, 30-40, 40-50 and >50 cm.

In the riparian zone on each bank, dominant trees were classified as pole sapling (including shrub), young forest, and mature forest, or roadway. The loss of meander bends and riparian zone by road development is summarized in Redfish Consulting Ltd. (2003).The zone was also classified as deciduous, conifer or mixed structure, and the percent canopy closure over the river was also visually estimated.

Further, within each hydraulic unit, percent useable fry and parr habitat was determined by consensus, by estimating sub-sections lengths and widths based on IFIM weighted useable depth and velocity criteria (“Delphi” curves obtained from R. Ptolemy pers. comm. 2002). Based on velocity measurements at a small sample of riffle transects on another river 1-2 months later, visual estimates underestimated useable fry habitat by 50 % on average. However, the two methods were near-similar on average for parr habitat in riffles (data on file).

A similar protocol was followed for all side-channels encountered in the 1-2 km sampled segments of the six mainstem reaches.

Values of the various parameters were converted to those required for FHAP diagnostics as percent pool (by area), pool frequency or spacing per channel

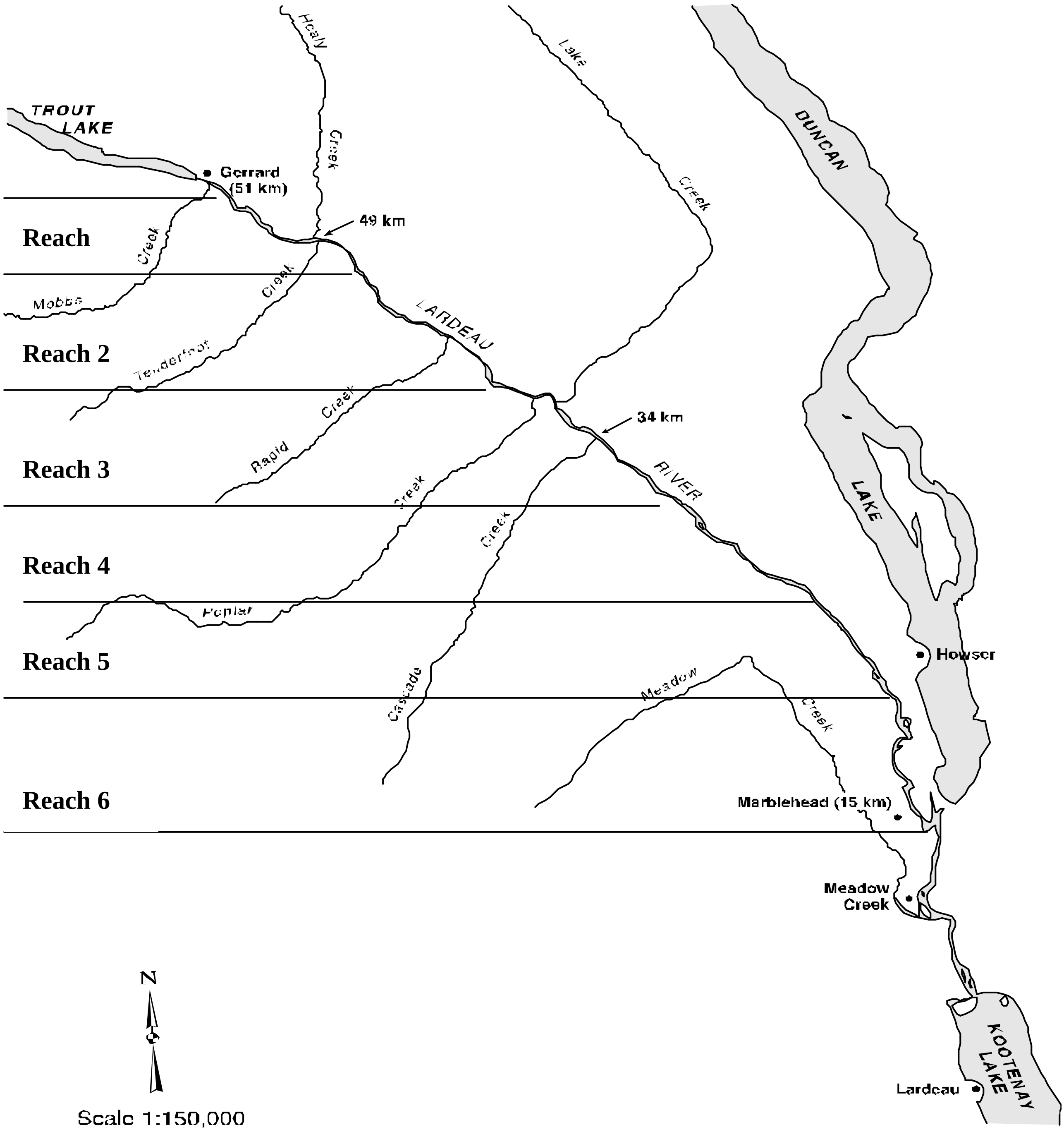

Figure 1. Lardeau-Duncan River system showing Reach location at the Lardeau River, 2002.

width, total large wood per channel width, functional large wood per channel width, percent woody debris in pools, percent boulder cover in riffles, percent total cover and substrate quality.

Sub-sampled sections were expanded by 3.83 to 6.93 times (mean 5.38) to obtain total lengths and areas. No attempt was made to place confidence intervals on the estimates because the variance in river features was typically large. Sub-sampling and expansion of estimates can yield significant errors, particularly if a feature is sampled that does not occur as frequently as elsewhere. For example, this may have occurred with a large side-channel in Reach 6, with the expansion (by 5.94) resulting in a larger than expected area of side-channel habitat.

Results and Discussion

Physical Features

Twenty percent of the length of the Lardeau River was sampled, with sampled lengths ranging from 1021 m in Reach 4 to 1671 m in Reach 1. Sampled area ranged from 45,370 m^2 in Reach 3 to 70,841 m^2 in Reach 6 (Table 1). Reach sample locations were as follows: Reach 1, 45-46.7 km (lower) lat. 50 29 476, long. 117 14 988 W; Reach 2, 42-43.5 km, lat. 50 27 029 N, long. 117 10 882 W; Reach 3, 38 km (lower), lat. 50 25 479 N, long. 117 08 595 W; Reach 4, within 27-32 km, lat 50 21 899 N, long. 117 02 858 W; Reach 5, 24.2 km (end) (no gps record); Reach 6, 20-21km, lat. 50 17 814, long. 116 58 154 W. Sub-sampled total length was 8.3 km of the total length of the Lardeau River (Table 1 and 2).

Table 1. Sampled lengths and areas of Lardeau River in 2002.

		Sampled Distance			Sampled Area			
Reach	Total Length m	Riffle m	Glide m	Pool m	Area m^2	Riffle m^2	Glide m^2	Pool m^2
1	1,671	644	486	541	55,587	21,452	18,295	15,840
2	1,559	871	150	538	59,002	29,617	4,791	24,594
3	1,284	408	661	215	45,370	13,048	27,298	5,024
4	1,021	885	0	136	46,160	41,488	0	4,672
5	1,191	648	384	159	55,453	32,879	16,931	5,643
6	1,586	707	606	273	70,841	34,409	26,313	10,119
Total	8,312	4,163	2,287	1,862	355,413	172,893	93,628	65,892

By length, reaches were comprised of more riffle than glide or pool, exceptin Reach 3 where glide was more prevalent. Reach 4 was highly dominated by riffle (89%) with no glides in the sampled section. On average by length, riffle comprised 52%, glide 27% and pool 21% for all reaches combined (Table 2).

Total wetted area of the river during early fall, 2002, was 1,771,078 m^2, and by area was comprised of 52.5% riffle, 28.1% glide and 19.3% pool (Table 3). By area, Reach 4 was almost all riffle (89%), and Reach 5 was also relatively high in riffle (59%). Glides dominated Reach 3 (60%). Pools comprised a low but significant area of Reach 3, 4 and 5 and 6 (10-14%), but were more prevalent in Reach 1 (29 %) and 2 (42 %) of the Lardeau River. (Expansion factors used obtain total areas for Reach, 1, 2, 3, 4, 5 and 6 were 3.83, 4.54, 5.51, 6.93, 5.94, and 5.52, respectively.)

Table 2. Total (expanded) lengths and percent riffle, glide and pool by reach in the Lardeau River in 2002.

Reach	Length m	Riffle m	% Riffle	Glide m	% Glide	Pool m	% Pool
1	6,400	2,467	38.5	1,861	29.1	2,072	32.4
2	7,080	3,954	55.9	681	9.6	2,443	34.5
3	7,080	2,248	31.8	3,642	51.4	1,185	16.7
4	7,080	6,133	86.6	0	0	942	13.3
5	7,080	3,849	54.4	2,281	32.2	944	13.3
6	8,760	3,903	44.6	3,345	38.2	1,507	17.2
Total	43,480	22,554		11,811		9,093	
Mean			51.9		26.8		21.2

Bankfull width varied considerably between the reaches. Reach 1 was relatively narrow at 46 m, but Reach 2 and 3 were about 2-fold wider at 93 and 107 m, respectively (Table 4). Very large bars were evident in these two reaches, yet wetted widths were narrower, similar to Reach 1. Overall, mean channel width of the Lardeau River was 72 m, almost twice the mean wetted with of 39 m, reflecting significant bar development. It is possible that channel widening has occurred in these reaches since riverbanks have lost old-growth root development. Mean riffle, glide and pool depths were 0.7, 1.0 and 2.0 m, respectively.

Table 3. Expanded wetted river area and % riffle, glide and pool in Lardeau R.

Reach	Area m^2	Riffle m^2	% Riffle	Glide m^2	% Glide	Pool m^2	% Pool
1	212,898	82,161	38.6	70,070	32.9	60,667	28.5
2	267,869	134,461	50.2	21,751	8.1	111,657	41.7
3	249,989	71,894	28.8	150,412	60.2	27,682	11.1
4	319,889	287,512	89.9	0	0	32,377	10.1
5	329,391	195,301	59.3	100,570	30.5	33,519	10.2
6	391,042	189,938	48.6	145,248	37.1	55,857	14.3
Total	1,771,078	961,268		488,051		321,759	
Mean			52.5		29.0		19.3

Dominant river substrates were cobbles throughout the length of the river and averaged 22 cm. Coarser cobble substrates were evident in Reach 1, 4 and 5. Mean estimated gradient and velocity were 0.42% and 0.6 m/sec, respectively.

Table 4. Mean bank-full width, wetted widths and depths of riffles, glides and pools in the Lardeau River in early fall 2002.

Reach	Mean Bank-Full Width m	Mean Wetted Width m	Mean Riffle Depth m	Mean Glide Depth m	Mean Pool Depth m
1	46	36.4	0.54	0.87	1.71
2	92.8	37.5	0.73	1.1	2.79
3	106.5	31.5	0.66	1.1	1.45
4	61.9	42.1	0.9		2
5	60.9	45.7	1	1.6	2.4
6	65.7	42.9	0.54	1.53	1.7
Mean	72.3	39.0	0.7	1.0	2.0

Table 5. Mean dominant and sub-dominant substrate sizes, and estimated gradient and velocity in the Lardeau River in 2002.

Reach	Mean Dominant Substr. M	Mean Sub-dom. Subst. m	Mean Est. Gradient %	Mean Est. Velocity m/sec
1	0.28	0.19	0.58	0.69
2	0.13	0.21	0.38	0.56
3	0.19	0.14	0.37	0.72
4	0.25	0.22	0.63	0.7
5	0.27	0.19	0.33	0.49
6	0.18	0.15	0.24	0.43
Mean	0.22	0.18	0.42	0.60

Large Woody Debris Frequency

Large wood was abundant throughout the Lardeau River, but much of this wood was high on bars with limited functionality, both hydraulically and biologically, although important geomorphologically for bar stabilization and re-vegetation over the long term (Table 6). More large wood was evident in pools (52%) than riffles (33%) and glides (19%). In Reach 4 in particular, large wood was dominant (70 %) in pools, yet riffles comprised 89% of this reach. This reach also had the lowest amount of large wood. Total counts of large wood per channel width, whereby jams are standardized as 10 pieces of LWD according to the procedural protocol, were: 4.5 in Reach 1, 28.8 in reach 2, 38.3 in Reach 3, 8.1 in Reach 4, 5.0 in Reach 5 and 10. 3 in Reach 6. These are all >2 pieces of LWD per channel width which is the threshold that is classified as "good" from the diagnostics of the procedure (Table 5 in Johnston and Slaney 1996). However, in bigger streams similar to Lardeau River, functional large wood should be utilized as the *primary* diagnostic because much of the distal bar wood has very limited influence on the hydraulics of the channel.

In all six reaches, total functional large wood was above the "good "rating of >2 pieces per channel width (Table 7). Reach 2, 3 and 6 were well above >2 per channel width. Reach 4 was 2 above, but Reach 1 and 5 were only about 1 above the threshold (2/channel width) of the "good" rating. Amongst large wood that occurs naturally in streams, larger sizes provide much of geomorphic and hydraulic functions, and mean diameter of large wood increases with stream size (Bisson1992). Amongst large wood that occurs naturally in streams, larger size

Table 6. Total large wood tally by reach, and percent composition in riffles glides and pools in the Lardeau River in 2002.

Reach	% Composition of Total LWD Riffles	Glides	Pools	Total No. LWD/Chan. Width
1	32.1	19	48.9	5.1
2	52.5	5.8	41.6	39.8
3	18.1	44.8	37	85.7
4	29.8	0	70.2	21
5	35.2	6.3	58.5	17.4
6	32.7	11	56.2	24.1
Mean	33.4	18.6	52.1	38.2

LWD provides much of geomorphic and hydraulic functions, and mean diameter of large wood increases with stream size (Bisson1992). Wood that is small (<30 cm) plays a minor role in the Lardeau River except as cover and as driftwood that adds to the larger and key pieces that form log jams. Of functional wood, small wood < 30 cm basal diameter comprised 48% in Reach 1, 62% in Reach 2, 50% in Reach 3, 44% in Reach 4, 55% in Reach 5 and 55% in Reach 6., or on average 52% per reach.

When small pieces of functional wood are excluded from the analysis, the numbers per channel width are: 1.6 in Reach 1, 4.2 in Reach 2, 5.7 in Reach 3, 2.4 in Reach 4, 1.5 in Reach 5 and 2.4 in Reach 6. From this perspective, Reach 1 and Reach 5 would rate only “fair” and Reach 4 and 6 would be close to the “fair”-“good” threshold of 2. However, Reach 2 and 3 would rate strongly within the good rating (Figure 7). If only large wood >40 cm is included, reach 2 and 3 still rate highly, but other reaches were below the “good” threshold of 2 per channel width. Overall, these results indicate the frequency of functional large wood rates as “good”, but when the small wood < 30 cm basal diameter (or second growth) is excluded, two of the six reaches only rate “fair” (Figure 2).

A tally of log jams of >10 pieces of large wood per jam was completed in the sampled 1.0-1.7 km reaches of the river. Two were in Reach 1, 4 in Reach 2, 4 in Reach 3 (including 3 in a series), 3 in Reach 4, 2 in Reach 5 and 5 in Reach 6. Expanded estimated total jams per reach were 8, 18, 22, 21,12 and 28, respectively, or an estimated total of 109, or 2.5 per km. Some jams were

Table 7. Number of pieces of functional large wood per channel width (CW) by size category (diameter) in Lardeau River in 2002.

Reach	Functional LWD/CW 10-20 cm	Functional LWD/CW 20-30 cm	Functional LWD/CW 30-40 cm	Functional LWD/CW 40-50 cm	Functional LWD/CW >50 cm	Functional LWD/CW Total
1	0.6	0.9	0.7	0.3	0.6	3.1
2	3.6	3.3	1.8	0.6	1.9	11.1
3	1.4	4.3	2.6	1.2	1.9	11.4
4	0.8	1.1	0.9	0.6	0.9	4.3
5	1.2	0.6	0.5	0.7	0.3	3.3
6	1.2	1.7	1.1	0.5	0.8	5.3

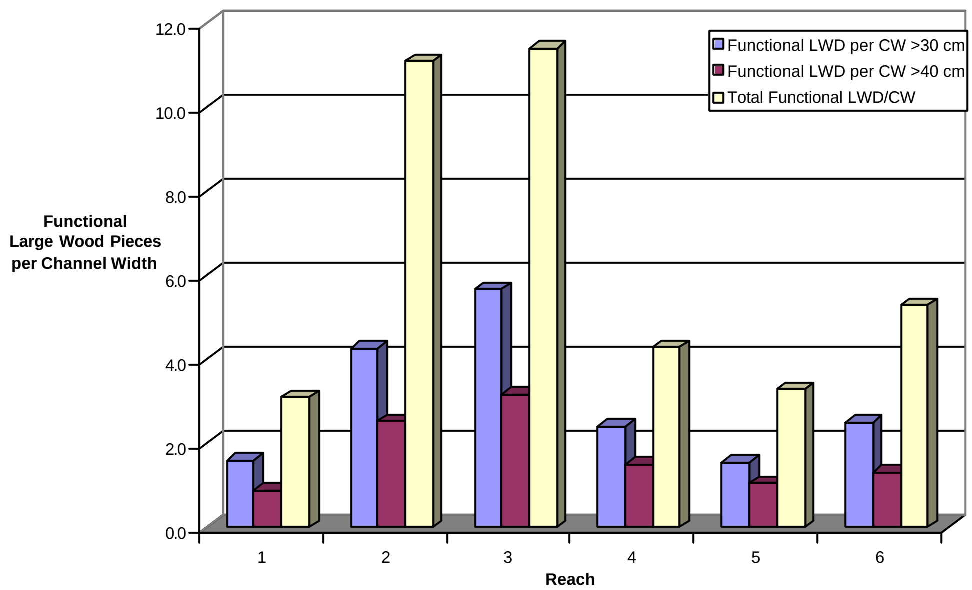

Figure 2. Total Functional large wood, and functional large wood > 30 cm and >40 cm diameter in the Lardeau River in 2002.

connected in a series (3 in reach 3), and the expansions may overestimate actual log jams. Some jams were connected in a series (3 in reach 3), and the expansions may slightly overestimate actual log jams. In the Duncan River, log jam generation has been terminated by the Duncan Dam operations, but the Lardeau River and to much smaller degree, Cooper and Hamill Creeks, have provided significant wood to the lower Duncan River.

Log jams are strikingly evident to those traveling by land or air along the river, but they are largely (60%) associated with pools which only comprise 18% the wetted area of the river on average. This is the reason the tally of jams as a maximum of 10 pieces provides a more realistic appraisal of the amount of large wood within hydraulic units of the river. Log jams of all sizes play a major role in the fluvial geomorphology and fish habitat of the Lardeau River, but caution is needed in extending their biological role beyond their local catchments (Fig. 3).

Figure 3. A typical log jam dominated smaller large woody debris in mid-Reach 3 of the Lardeau River in 2002. Note evidence of bank erosion and probable channel widening at the riparian young forest interface with the Lardeau river.

These results indicate that total large wood is relatively abundant in the Lardeau River. Yet, at a functional level, habitat managers should be perceptive of a trend towards smaller wood, with less larger wood that drives much of the Lardeau River's geomorphology and its salmonid habitat. Past wood recruitment was dominated by old-growth to mature cedars and cottonwoods (Figure 4), and the former are dominant in most of the larger log jams of the river today. Existing moderate levels of larger wood in most reaches appears to reflect long-term shifts within the primary sources of large wood to the Lardeau River, which is likely to affect the quantity of prime salmonid habitats in the future.

Riparian Structure and Functions

Large wood in the Lardeau River is contributed from three primary sources as: (1) driftwood from Trout Lake, (2) tributary transport and (3) riparian areas of the river, the latter via both windfall and erosion processes. Natural or logging-induced landslide events from main valley hill slopes are very sparse and do not appear to contribute large wood sources to the river. Of the seven tributaries, only Mobbs Creek is noted for periodical debris flow events, and the bridge at Gerrard has not historically accumulated jams of large wood consisting of whole trees. Thus, it is the riparian areas of the large Lardeau floodplain that contribute the majority of the large wood to the river system. In rivers, as at the Lardeau, lateral movement of meander bends within the floodplain is the greatest

Figure 4. Old-growth red cedar stands were prevalent throughout much of the Lardeau floodplain, which is still evident by the stumps on riparian banks (Fig. 5) and an abundance of cedar logs and rootwads in the logs jams of the river.

contributor of LWD in the system, and historically resulted in the numerous jams which at their core are largely of old-growth origin.

Riparian forests in all reaches are not dominated by mature forests because of historical logging or land clearing to the river banks (Table 8). Thus, there was a very low percent mature forest on both banks in all reaches. On one of two streambanks, mature forest only accounted for 6.4% of riparian tree cover on average, which was largely in Reach 4. Young forest and pole sapling were more prevalent forest types, and because pole sapling was mainly a succession species on floodplain bars, young forest was the predominant forest cover of riparian streambank areas. Young forests are trees up to about 80 years of age in the riparian area of the Lardeau River. Trees appear to be mainly 25 to 50 and 50-100 years of age in the in the upper and lower reaches, respectively. However, no age assessments of riparian trees were made.

Table 8. Riparian conditions of the Lardeau River in 2002, including % maturity of riparian forest (MF = mature forest, YF = young forest, PS = pole sapling).

Reach	Mature Forest	Young Forest	Pole Sapling	PS/MF MF/PS	YF/MF MF/YF	YF/PS PS/YF	Road/PS
1	0	42.9	14.2	4.7	4.7	19	14.2
2	0	16.6	50	8.3	0	16.6	8.3
3	0	36.4	63.6	0	0	0	0
4	0	14.3	0	28.6	14.3	42.9	0
5	0	22.2	0	0	0	77.7	0
6	0	0	50	0	0	40	10
Reach Mean	0	22.1	29.6	6.9	3.2	32.7	5.4

Mixed deciduous and conifer forests plus deciduous forest alone, comprised 96 % of the riparian forests, and thus coniferous riparian zones were almost non-existent (Table 9). This is to be expected because the riparian portion of the floodplain is frequently a mix of both vegetation types except where conditions are wet and these are largely deciduous. Regardless, large conifer stumps, particularly Western Red Cedar, were evident on the banks (Fig. 5).

As a common disturbance indicator, bank erosion was evident in numerous geomorphic settings including straight channels and the outside of meander bends, particularly in Reach 2 and 3 (Figure 5, 6, 7, 8 and 9). How much the

Table 9. Riparian structure and percent canopy closure of the Lardeau channel.

Reach	Riparian Forest Structure Percent Conifer	Percent Deciduous	Percent Mixed	Canopy Closure % Channel Width
1	6.3	37.5	56	5
2	0	50	50	1.7
3	0	89	11	1.1
4	0	0	100	1.4
5	17	17	67	2.4
6	0	80	20	1.8
Mean	3.9	45.6	50.7	2.2

Figure 5. Riparian second growth showing evidence of old-growth stumps from historical riverbank logging.

Figure 6. Typical riverbank erosion at a Reach 2 meander bend in Lardeau River

Figure 7. Riverbank erosion along a straight section of Reach 2, Lardeau River.

Figure 8. Riverbank erosion along a straight section of Reach 2, Lardeau River.

Figure 9. Riverbank erosion along a large meander bend on the right bank, with extensive bar formation on the left bank in Reach 3 of the Lardeau River in 2002.

bank erosion process has accelerated by a lack of a mature forest is uncertain. However, the expansive bankfull channel width in Reach 2 (93 m) and Reach 3 (107 m), which was 3-fold that of the late summer-fall wetted width and about 1.7-2-fold that of other reaches, suggests that widening as result of past streambank logging is in progress as described by Millar (2000). A detailed analysis of historical air photos would be needed to confirm if the channel of the Lardeau River is widening in response to past logging, as root masses decay and small 2nd growth riparian trees regenerate over time.

Pool Habitat Features and Cover

Primary pool spacing of six channel widths per pool is the average spacing found in nature (5-7 widths; Newbury and Gaboury 1997). Only Reach 5 (10) and 6 (12) were higher, but within the expected range because the distribution in nature is wide, ranging from 3-20 in pristine streams. The fish habitat assessment procedure also incorporates secondary pools or "pocket" pools (>20 m^2) within other hydraulic units. Such pools were sparse, particularly in Reach 4 and 5 (Table 10). Based on the procedural diagnostics, Reach 2, 3 and 6 rated "good", but Reach 1, 4, and 5 rated as only "fair". On average percent pool area at 19 % rated as "poor", and only one reach (2) was within the "fair" category at >40 %. However, this is not a result of low frequency of primary pools which repeated on average every six widths, but rather a low frequency of sub-pools or pocket pools. Yet, in a river the size of the Lardeau, one would not expect 55% pool LWD as in small streams, and thus, 40-55 % is over conservative for rivers. Regardless, the frequency of "pocket" pools is relatively low for a river (Table 10). These are typically caused by obstacles along riverbanks including rootwads and fallen trees, but there is virtually no large wood to wind-throw or enter via decay into the wetted channel. This "early warning" indicator was particularly evident in Reach 4 where such pools were sparse.

Fish habitat cover rated "fair" in most categories. Cover in pools was high, particularly in Reach 1. Depth, turbulence, boulders and LWD comprise pool cover for juvenile rainbow trout and other species. Thus, deep pools of a large stream typically have high cover ratings unless river flows are at a low percentage of mean annual flow. Cover in glides was moderately low on average, and in riffles was < 5% in Reach 1, 2, 3 and 5. From the fish habitat diagnostics, boulder cover in riffles rated as "poor", but this was primarily a result of the relatively low gradient of the Lardeau River, and boulders were only significant in reach 4 (Figure 10; 10%). Lag-type boulders originating from hillslopes were evident in Reach 1, but were also sparse. In-filling of boulders as a disturbance indicator was not rated, but did not appear excessive in reach 4. Boulder substrates were relatively few compared to most steelhead rivers (e.g., Chilliwack River).

The percent LWD in pools averaged 10 % and ranged from 6 to 19, and thus all reaches rated as “fair”. Total cover averaged 15 % (Figure 11), and ranged from 10 % to 22 %, and rated “fair” except in Reach 1 which rated “good”.

The primary cover feature in the Lardeau River was LWD, averaging 56 % in percent composition of cover types, with depth second at 20 % and bank vegetation third at 13 %, followed by boulders at 8 %. The secondary cover feature was also dominated by LWD (37 %), followed by percent boulders (31%), vegetation (11 %) and depth (9 %). Cutbanks and turbulent surface cover were insignificant (1-6 %). Cutbanks are normally a key feature in rivers with mature riparian forests with substantive root masses. Therefore, their scarcity is another disturbance indicator that should be examined in more detail by comparisons to river segments with mature riparian forests. Large wood is crucial for cover in the Lardeau River. Furthermore, its geomorphological role in scouring deeper pool and run habitats required by parr-sized trout and other fish is striking.

Side-channel Habitat of the Lardeau River

Side channels are common at the Lardeau River within each reach and provide both fry and parr habitat , particularly the former. Twelve side channels were surveyed, ranging from one in Reaches 6 and 4, two in Reaches 1, 2, and 3, and four in Reach 5 (Table 11, Fig. 12). Average bankfull and wetted width in fall was 26 m and 6.2 m. Total (expanded) wetted area was 141,300 m^2 (Table 12).

Table 10. Pool characteristics in the Lardeau River by Reach in 2002.

Reach	Number of Primary Pools	Chan. Widths/ Primary Pool	No. Sub-Pools	No. Total Pools	Channel Widths per Pool	Mean % Pool by Area
1	8	4.5	3	11	3.3	28.5
2	6	2.7	10	16	1	41.7
3	4	3	7	11	1.1	11.1
4	3	5.5	3	6	2.8	10.1
5	2	9.8	4	6	3.3	10.2
6	2	12	17	19	1.3	14.3
Total	25		44			
Mean		6		12	2.1	19.3

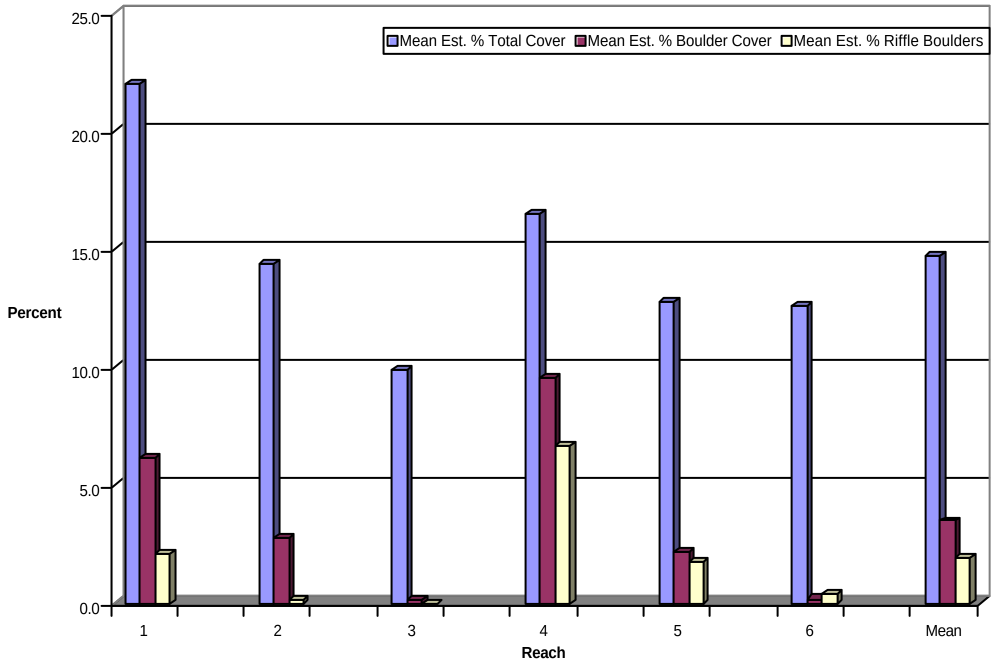

Figure 10. Total cover, total boulder cover, and riffle boulder cover in the Lardeau River in early fall, 2002.

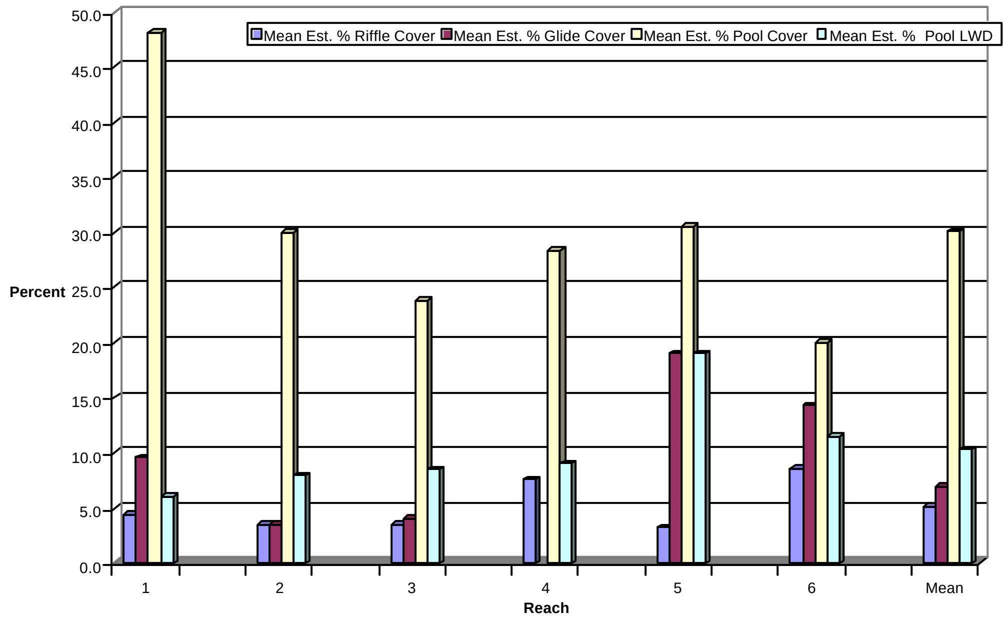

Figure 11. Estimated percent fish habitat cover in riffles, glides and pools, and percent LWD of pools area in the Lardeau River in 2002.

LWD was also prevalent in side-channels because most originated at log jams. Total LWD and functional LWD per channel width rated “high” on average. Thus, percent cover was significant, or 12% on average. Velocities and depths favoured fry rearing over parr, and estimated percent useable fry habitat averaged14.5 % versus 5.2 % parr habitat. This was the reverse of the mainstem where parr habitat was estimated to be 3-4 times that of percent useable fry habitat (Redfish Consulting 2003).

Thus, side-channels are a significant habitat feature in the Lardeau River system, but they only account for 8 % of total wetted area by fall. several were historically cut-off by the road system (Slaney and Andrusak 2003), and many have shrunk to narrow near-dewatered channels. Of the flowing ones, log jams control flow at their inlets and thus any reduction in the size and nature of these jams would cause detwatering. Some that were cut-off can have flows restored by installing culverts, and some of those dewatered could be restored as active jam/sill-controlled side-channels (e.g., Reach 4)

Trends in Habitat Generating Processes of the Lardeau River

As a disturbance indicator, a worrisome trend on the river is that the second growth riparian forest is still highly dominated by a small “young forest” re-growth. Other than sporadic old-growth stumps, there appears to be little natural recruitment of >30 cm diameter large wood from erosion and wind-throw processes. This is evident in the large wood accumulations in the river channel

because wood <30 cm comprised 52% of functional large wood on average and was 62% in Reach 2, as is evident in Figure 3. Further, when large functional wood > 30 cm is used as the diagnostic, large wood is within the “fair” rating in two of six reaches. Given the dominance of young trees in the riparian forests, large wood in the river is more likely to decrease over time via decay and transport of >30 cm large wood.

It is evident that LWD is a critical habitat generator for Gerrard rainbow trout, as well as a feature that creates a geomorphic dynamic equilibrium in the Lardeau River. Thus, the amount in the river should be re-tracked at 10 year intervals to ensure sufficient lead time is available to address any deterioration of habitat conditions. The key factor that has “saved the river” with its renowned Gerrard rainbow is the predominance of Western Red Cedar among the existing accumulations of large wood. It also should be noted that the incidence of large wood in wetted channels is also important for driving fish food chains. Aquatic insect abundance decreased 4-fold after woody debris removal from a southeast US stream (Symposium on the role if wood in world rivers, 2000, Corvallis, Or.)

Table 11. Length, area bankfull width and wetted with of 12 side-channels in six reaches surveyed in 2002.

Reach	Total LWD/ Channel Width	Functional LWD/CW	% Cover
1 SC 1	2.9	1.21	13.2
SC 2	4	3.4	28
Mean	3.5	2.3	20.6
2 SC1	0.7	0.66	4.3
SC2	1.4	1.22	11.6
Mean	1.1	0.94	8
3 SC1	1.2	0.68	7
SC2	11.3	4.5	10.8
Mean	6.3	2.7	8.9
4 SC1	6.3	2.2	
5 SC1	0.3		
SC2	3.5		
SC3	8.0		
SC4	2.0		
Mean	3.5		
6 SC1	5.6	2.5	11.2
Mean	4.2	2	12.3

The decay rate of large wood in streams is 3% on average (Bisson et al. 1992), but cedar is about half this rate, and in addition large diameter logs decay about half the rate of small logs. Thus, residual mature to old-growth cedars of > 30 cm basal diameter in the channel, have delayed potential channel widening or unraveling and loss of crucial habitat features that has occurred on other streams (e.g., Millar 2000). Yet, the existing second growth forest is slow to mature, and the ultimate question is whether the in-channel large wood will have diminished before the recruitment of large-sized second growth recovers. At this time, much of the large wood entering the channel is from the erosion processes at meander bends, and is small in diameter, particularly in the middle to upper river reaches. This is evident in Figure 3, and from riparian trees cover evident in Figure 5-9.

Table 12. Estimated length (m) and area (m^2) of side-channel habitat in six Reaches of the Lardeau River in early fall 2002 (expanded).

Reach	Length km	Expanded Length m	Expanded Area m^2
1	6.4	1471	6,030
2	7.08	2252	17,564
3	7.08	3978	33,019
4	7.08	5045	33,297
5	7.08	2418	5,802
6	8.76	2534	45,606
Total		17,697	141,319

Figure 12. Log jam-controlled side-channels provide prime fry rearing and some parr rearing habitat in the Lardeau River (Reach 2).

Figure 13. A large meander bend side-channel of Reach not isolated from mainstem flows, but still providing prime fry rearing habitat during summer to fall in the Lardeau River (Reach 3).

Another disturbance indicator is riverbank erosion, which was prevalent in Reach 2, particularly on the left bank (Fig. 5-9), and to a lesser extent on both banks in Reach 3 where there is more coarse materials and bedrock on the left bank. In these reaches, bankfull width (93 and 107 m) was 58% and 80% greater than the mean width (59 m) of the other four reaches. An analysis of historical air photos would detect if channel width in these reaches is widening and if the rate may be accelerating as the volume of large wood declines over time in the channel. Thus, there are signs of unraveling that should be tracked periodically. If confirmed as accelerating, stabilization is feasible with debris groins, designed to catch and accumulate driftwood, using excess rootwads that are isolated high on large bars. However, the extent of widening should be examined more closely using air photos combined with full reach assessments in Reach 2 and 3.

Pool ratings also trended towards “fair” in half of the reaches because of the frequency of secondary or “pocket” pools, typically generated by tree-rootwad obstacles along riverbanks. This results from very limited large-diameter tree inputs. Mature trees that wind-throw, hang up on banks and create habitat where they project into the wetted channel or where their rootwads erode into the channel. Low pool incidence is an early warning indicator which was particularly evident in Reach 4 where such pools were almost lacking except in one riffle. Pool scarcity was likely caused by historical log drives in this reach because there was evidence of old cut-off cedars at 45^{o} that extended over the river.

These lower river log drives were prone to “hang-ups” in the river (Alexander 1998). This reach did have some mature cedar, which may have been too small during harvesting of trees in this reach. Currently it appears to be at an age when LWD recruitment is at a minimum (about 80-100 years) before re-supply initiates at about 100 years of age, and its maturing nature starts to impart some stability to the riverbanks (Fig. 14). Reach 5, and to a lesser degree Reach 1 also lacked such pocket pools, which are likely to decline further yet.

Figure 14. Parr habitat associated with a large log-jam lodged at the entrance to a 700 m de-watered side-channel, and mature riparian forest cover in Reach 4.

In reach 4, almost all (89%) of the wetted area was comprised of riffle. There, and to a lesser degree in Reach 5, large wood restoration should be pursued incrementally to ensure secondary pools are recovered, This should be undertaken by using a similar template as in Figure 15, which is very similar to the triangular or A-log design described in Slaney et al. 1997. This was demonstrated to have stability and high functionality in several rivers where it was tested (D’Aoust and Millar 1999). A more recent design ensures bank protection and captures driftwood, and it is strikingly similar to the natural template in Figure 15. Accordingly, it is generally accepted that restoration should focus on restoring natural processes (Roni et al. 2002).

Large wood loss in nature occurs at 10% a decade, declining to 5% a decade after about 50 years at this latitude in the “interior wet belt” (Koski 1992).

Figure 15. A natural log jam template that has resulted in a scour pool/run in Reach 4, and that provides prime rainbow parr habitat, as well as bull trout, mountain whitefish, and kokanee habitat in the Lardeau River in 2002. Note the keystone species, kokanee, in the foreground which supply significant nutrients and energy (eggs/fry) for production of Gerrard rainbow trout and other species.

Unfortunately, re-supply of large wood does not initiate until about 100 years and does not fully recruit LWD until after 150 years. The cycle may be extended in this biogeoclimatic zone (hemlock-cedar) where cedar is a dominant climax vegetation type on floodplains. If the condition of reach 4 is foreshadowing where the river may be in the next 50 years, conditions are going to deteriorate before they get better, although the functional condition of the six reaches at this time interval overall rates about 50% "good" and 50% "fair".

Duncan River Trout Habitat

Duncan River is comprised of two reaches above and three below the Lardeau River confluence, and it is 11.7 km in total length (R.L. & L 2000). The Duncan River is comprised of five short reaches. Reach 1 is 1.3 km from Duncan Dam to the Lardeau River confluence. Reach 2 is a 1.6 km canyon reach downstream of the Lardeau River confluence, and Reach 3 is a 3.1 km braided channel upstream of Hamill Creek. Reach 4 is a 1 km segment from Hamill Creek to Cooper Creek confluence, and Reach 5 is a low gradient braided channel from Cooper Creek to the mouth of at Kootenay Lake. (All reaches of the river were inspected on October 29, 2002, during high water releases, that typically occur from June to October and November to March each year.) The flow regime in the river contrasts with a normal spring freshet of inland rivers in the Columbia Basin, or from late April to July as at the upper Duncan River and the Lardeau River. From observations in late October, 2002, the "mesohabitats" classified as "runs" included wide river glides.

Depending on size, juvenile trout migrate down the Lardeau as lakeward migrants and as displaced juveniles, which are searching for further suitable habitat to rear (Irvine 1978). Evidence from other studies conducted at Okanagan Lake and elsewhere indicate that underyearling (<50 mm) survival in large lakes with piscivorous predators is negligible (Sebastian 1979, Burrows 1993). Early studies of migration at Marblehead at Lardeau River showed that >100,000 underyearlings (30-35 mm) migrated further downstream into the Duncan River in mid-summer (Irvine 1978), where further rearing would occur. Similarly, some yearlings would also be displaced as parr grow larger in size in the Lardeau, and require favourable downstream habitats until they reached a size required for survival in Kootenay Lake (Irvine 1978). Thus, the quantity of useable habitat and its productivity is important in the Duncan River. Compared to the Lardeau, the Duncan is about 28% the length of the Lardeau, and the Duncan has a wetted area of 789,000 m^2 or about 30% of the Lardeau. It potentially made a significant contribution to Gerrard and Duncan rainbow trout production historically.

"Mesohabitats" in the Duncan River were surveyed and classified in mid-September, 1999 (R.L. & L. 2000), when the river was flowing at 197 m^3/sec (7000 cfs) The results of this study and other investigations, were further summarized by Vonk (2001). Habitat-related information on the Duncan River is summarized below from these reports, and integrated with that of the Lardeau River:

Reach 1 (1.2 km: largely mainstem fast run)

Run habitats dominate Reach 1 except for an atypical section in the upper portion, water velocities and turbulence vary greatly with flow releases from Duncan Dam. Velocities are fast at the margins at higher water discharges. The old river channel is now a snye and is offset at the Dam's plunge pool which is turbulent. The wetted area of the reach is 96,700 m^2 and is comprised of 71% snye-/log-jam/bar and backwater, 24% run, and 5% rapid. There are no pools, riffles or flats in this reach. Other than the log jam at the confluence with the Lardeau, this reach would be expected to support few Gerrard or Duncan strain rainbow trout owing to its excessive turbulence, and the off-set syne is probably of limited habitat value owing to slack water conditions.

Reach 2 (1. 6 km; largely mainstem fast run)

Run habitat dominates (74%) of this 1.6 km canyon-like reach with a wetted area of 39,100 m^2. The remainder is comprised of 17% riffle, 7% flat and 2% snye. As in Reach 1, velocities and depths were observed in late October, 2002, to be excessive for summer fry rearing, and only useable for parr rearing for about 1-2 meters m from the river bank. Roots and vegetation provide cover within narrow useable widths for parr, but depths > 0.5 m are excessive for fry.

Reach 3 (3.1 km: largely mixed trout habitats dominated by side channels)

Reach 3 is much more variable and is diverse in macro-habitats and microhabitats for salmonids, and has a wetted area of 276,800 m^2. It is comprised of a braided reach where side-channels dominate habitats. A sizeable snye or slough comprises 32% of the wetted area, but is unconnected upstream to the mainstem. The mainstem is comprised of 3% riffle, 20% run, and 77% other features including 32% snye and 11% log jams/bar and 34% mixed habitats of riffle, run and flat, the latter presumably in the side-channels. Velocities and depths were more variable and useable for rearing of fry and parr within side-channels, but mainstem depths and velocities were again largely outside the range for summer use by salmonid fry and parr. Habitat of parr was limited to the inner margins, unless an old jam or fallen trees created wider useable areas for parr. Habitat for both fry and parr in this reach was more favourable than Reach 1 and 2 because of side-channel development (fry), a wider margin, and old jams available for mainstem rearing (parr).

Reach 4 (1 km: largely mainstem fast habitats)

Reach 4 is defined by the confluences of Hamill Creek to Cooper Creek, and is 1 km in length, with an area of 39,400 m^2. Macro-habitats are comprised of 45% riffle, 47% run, 4% backwater, 3% pool and 1% snye. As in Reaches 1 and 2 this reach has mainly unfavourable depth and velocity conditions in summer to fall for trout underyearlings, and limited margin habitat for parr rearing at high flows.

Reach 5 (4.7 km mixed margin/log-jam and side-channel habitat that grade to slack waters towards Kootenay Lake)

Reach 5 extends 4.7 km from Cooper Creek to Kootenay Lake, is extensively braided, and has an expansive area of 305,400 $m^{2.}$ This reach consists mainly of multiple active channels, and is comprised of 29 % riffle-run-flat complexes (presumably mainly in side-channels), 25% run-glide, 25% flat, 10% log-jam/bar habitats, 6% riffle and 4% rapid. Of note, log jams are significant in this reach which is much wider than other reaches, and thus, large wood hangs up on bars. This reach has mixed rearing habitat conditions. It is too expansive and slow in the sub-reach near the lake, but is too fast and deep for fry rearing in the upper portion. However, displaced yearling parr would find useable rearing velocities and depths in the several log jam areas and along the margins.

Salmonid Habitat, Flow Stage and Nutrients

Overall, the Duncan River has a diversity of habitats, but the high flows from mid-summer through fall are not conducive to underyearling rearing. These conditions would force displacement of most rainbow trout underyearlings into marginal habitats or out into Kootenay Lake. In sharp contrast to Lardeau River, pools are extremely rare in the river, but run habitat is prevalent. Runs are unlikely to offset the lack of primary pools for parr rearing, owing to their high velocities in the growing season. There are some suitable habitats particularly where side-channels are active and there are numerous log jams (total, 80), but if side-channels were dewatered and then re-submerged at high flow release levels, these would be mostly unfavourable environments for underyearlings and parr. Of the side-channel habitats, velocities were favourable mainly for fry, but depths in some were excessive at high flows and outside the useable weighted range. Others were more favourable or useable velocities low (as in side-channel H4, where depths were suitable at most flows). Side-channels include: 10 backwaters, 21 synes, and 47 active side-channels, but it is the active side-channels and snyes with some useable velocities and depths that would support juvenile trout and other salmonids under the altered hydrological regime.

There were also 6.4 km of eroding banks that probably reflects the lack of an old-growth riparian forest, plus agricultural land clearing and high discharges from Duncan Dam. However, there was 1.1 km of cutbanks which was much greater than that recorded on the Lardeau River, where cutbanks were not common. This was likely because of the more mature riparian forest and the high discharge levels at Duncan River, owing to reported bank erosion (R.L.& L. 2000).

There has been an 80 % reduction in the magnitude of the spring and summer flood flows and a corresponding 100 % increase in mid-summer to fall flows (Fig. 6 in Vonk 2001). Preliminary observations indicate this has significantly reduced the amount of useable habitat for juvenile rainbow trout (Figure 16, 17), particularly for underyearlings that historically migrated in large numbers into the Duncan River during July and August (108,000; Irvine 1978). Parr habitat also appears to be reduced, but less so, and velocity and depth measurements would be required to assess weighted useable widths over a significant sample of replicated partial transects. Systematic velocity and depth sampling across transects at different flow stages, using the Lardeau as a spatial control, should provide an estimate of the impacts of the shift in flow regime. Such measurements should be carried out as part of further habitat and fish abundance surveys on the Lardeau River. If impacts are as significant as predicted, a more comprehensive investigation should be conducted. Of note, rainbow trout comprised a very small percentage of sample catch or 6% (< 100 mm in length) of sport fish, and 3 % of all fish in mid-September 1998 (Vonk 2001).

It has been reported that prior to impoundment, the Duncan River exhibited physical characteristics typical of glacial systems fed by glacial runoff and snowmelt (Vonk 2001). Yet, the Duncan system was lake-headed in 1964, and Duncan Lake settled out glacial sediments, even in the spring. Only one mountain stream, Glacier Creek, contributed some glacial sediments during spring runoff, 1 km below Duncan Lake, and even during this period, most sediment-laden waters originated from the Lardeau River (Note: the senior author operated a boat near-daily during 1964 on the Duncan River from spring to late summer, and traveled from Duncan Lake several times a week downstream to at point near the Lardeau confluence.)

Physical habitat is only one component of rearing habitat of all species, and other factors including water temperature, total gas pressure and seasonal nutrient concentrations can also have profound effects on fish populations in tail-race conditions. Nutrients, in particular, set carrying capacity in streams as much as physical habitat, and nutrient rich waters carry 2-5 times the salmonid biomass per unit area of infertile waters (Ashley and Slaney 1997). There is evidence that average annual temperatures at Duncan River are similar to pre-impoundment, but average summer temperatures are cool (Perrin and Korman 1997). Further, total gas pressure is generally <110 %, except at extreme spill events, and there is sufficient depth that compensation (1 % per 10 cm) may occur, yet underyearlings are not found significantly in deep waters >0.5 m. However, oligotrophication of the Duncan River is a potentially profound impact that was overlooked by Vonk (2001) as a riverine impact. A comprehensive study of nutrient retention in Duncan Reservoir by Perrin and Korman (1997) concluded that there was significant removal, depleting TP concentrations to Duncan River, and thereby into Kootenay Lake, by as much as 56 %.

Total P is bound in dissolved organics and particulates, including planktonic biota, but some is converted to inorganic P by biological processes of the river. Well replicated nutrient data from Perrin and Korman (1997) indicate that in summer in the Lardeau River and Duncan River (the latter above their confluence), mean dissolved NO_3-N concentrations are 78 µg/l and 150 µg/l, respectively, and thus nitrate nitrogen is not limiting autotrophic production. However, in the Lardeau River, mean dissolved SRP and Total P are 0.9 µg/l and 1.7 µg/l, respectively, and the molar mean N:P ratio is high (211); thus, P is significantly limiting autotrophic production. In the Duncan River, mean dissolved SRP and Total P are 0.5 µg/l and 1.7 µg/l, respectively, and the mean molar N:P ratio is extremely high (719). Thus, autotrophic production and the insect-fish food chain is highly limited in the Duncan River by very low SRP concentrations associated with extremely low molar N:P ratios. Summer concentrations SRP concentrations <1 µg/l are rated as “poor” or deficient (Johnston and Slaney 1996, Ashley and Slaney 1997).

Figure 16. Typical marginal rearing habitat conditions for underyearling rainbow trout in the Duncan River during late October, 2002.

Figure 17. Parr rearing habitat is provided by fallen trees (foreground) and old log jams (mid-background - left bank) in the Duncan River (late October, 2002).

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Useable habitat of Gerrard trout, and any residual Duncan strain of rainbow trout, appears to have been reduced significantly by shifting the peaks of the hydrograph sharply into summer-fall and then maintaining high flows into winter, with probable reduced nutrient availability for autotrophic production. Thus, the overall productivity of habitat of Duncan River for rainbow trout and other salmonid species has likely been reduced significantly. Further examination is needed to determine the degree of impact and what remedial measures can be employed to offset such impacts. Offsetting the loss of habitat quality of the Duncan River for Gerrard rainbow trout becomes much more crucial when the long-term decline in Lardeau habitat, related to past riparian logging is taken into account.

Summary and Recommendations

A fish habitat assessment was conducted in early fall of 2002 on a stratified random sub-sample of 20 % of the Lardeau River to ascertain the status of Gerrard rainbow habitat. The river was stratified into six reaches that ranged in length from 6.4 km to 8.8 km. In addition, an earlier study of macro-habitats in the Duncan River was reviewed and the results integrated with the Lardeau River assessment. Regardless of a sub-sampling approach, some profound trends were evident that provide an "early warning indicator "on future habitat status:

- Habitat conditions in all reaches of the Lardeau River are highly driven by the existing large wood within the river channel, plus its primary re-supply from the riparian areas of the floodplain;
- Large wood is abundant in all reaches, with extensive log jam development, and was particularly plentiful in the mid-river reaches (2 and 3) and the lower-river Reach (6), and as total channel LWD, rated as "good" based on the procedure;

- The quality of functional large wood varies greatly between reaches and when wood >30 cm basal diameter is examined, the rating was only "fair" or near-fair in 50 %, which is a concern.
- Several pool and cover characteristics rated more within the "fair" range than "good" range, and large wood played a dominant role over all other cover types. A low incidence of secondary or pocket pools, rather than frequency of primary pools, lowered the pool and cover ratings. The low numbers of secondary pools reflects the dominance of young forest within the riparian zone. Reach 4, in particular was highly dominated by riffle (89 %) with very few pocket pools, although the forest is currently maturing.
- Riparian conditions are highly dominated by young forest and secondarily pole sapling, the latter largely as a succession stage in meander bends. This condition is expressed in the large wood of the river which is trending towards smaller pieces (on average 52 % < 30 cm basal diameter) which is predicted to increase in frequency. As existing larger diameter wood gradually decays and is transported over time, re-supply will be mainly from small diameter wood <30 cm. Fortunately, the relatively high incidence of Western Red Cedar in the channel, which decays more slowly, is delaying a reduction in crucial habitat features of Gerrard rainbow trout.
- There is significant bank erosion in Reach 2 and to a lesser extent in Reach 3, and further channel widening is probable; these reaches are currently 60-80 % wider than other reaches.
- Side-channels were well developed in all reaches and provide significant fry habitat, whereas parr habitat was much more abundant than fry habitat in the mainstem;
- In the Duncan River, diverse habitat units exist with significant side-channel development in some reaches, but pools were non-existent (0.2 %), and the river flowed at high velocities and depths well into the vegetated edge of the riparian zone in mid-summer to fall. Useable underyearling habitat appeared to be sparse, although this was not quantified by hydraulic unit as at the Lardeau River, nor in an earlier study of the Duncan River in 1998-99 (R. L. & L 2000). Yet, historical records of underyearling movement (108,000) from the Lardeau River indicates that such habitat was likely important for mid-summer to fall rearing of Gerarrd rainbow in the Duncan River, based on size-survival relationships from scale back-calculations in other lakes . There is also some evidence of oligotrophication of the Duncan River which would limit production of all fish species including Gerrard rainbow parr.

- Recommendations are as follows:

    - Owing to the high importance of Gerrard rainbow trout, habitat conditions of the Lardeau River should be tracked by B.C. Fisheries at intervals of at least every decade owing to a unfavourable trends in large wood supply to the channel;

- A trend towards channel widening in the mid-river reaches should be explored in more detail via historical air photo analysis, and if confirmed, and there is a significant risk of further habitat impacts, selective banks stabilization with LWD should be prescribed;
- Some proactive restoration efforts should proceed incrementally to ensure future losses of habitat features are off-set, particularly in Reach 4 and 5 of the Lardeau River, with restoration of fish access (see Redfish Consulting Ltd. 2003 for losses) and re-activation of selected large wood-filled side-channels as a sound habitat options of highest priority;
- Consideration should be given to conservative thinning of existing young riparian forests in the middle to upper river, combined with slow-release fertilization, to accelerate the re-establishment of a mix of mature riparian conifer and cottonwood species; restoration of rail/roadway losses of riparian trees is a priority where feasible (see Redfish Consulting Ltd. 2003 for kilometers impacted);
- A seasonal assessment of weighted useable fry and parr habitat at replicated partial transects in the Duncan River, using the Lardeau as a control, should be undertaken by B.C. Fisheries. Also, the degree of oligotrohication should be examined more rigorously. The highly altered flow regime of the Duncan River appears to have eliminated much of underyearling habitat that would be historically utilized by Gerrard rainbow trout, and habitat and productivity losses may need to be off-set.
- Given trends and risks in the Lardeau related to past logging of river banks, and current dominance of young riparian forest stands, a greater emphasis on active management of salmonid habitat and its productivity in the Lardeau-Duncan system by BC Fisheries is advised to ensure habitat impacts and risks are proactively managed.

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